# IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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| Applicant: | Ramin Shahidi | |
| Application No.: | 10/610,960 | Art Unit: 3737 |
| Filed: | 6/30/2003 | |
| Title: | METHODS AND APPARATUSES FOR MAINTAINING A TRAJECTORY IN STEROTAXI FOR TRACKING A TARGET INSIDE A BODY | Examiner: BOR, HELENE CATHERINE |

## DECLARATION UNDER 37 CFR 1.131 AND 37 CFR 1.68

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

I, Ramin Shahidi, declare as follows:

1.    I am over the age of 18 and a resident of the State of California. If called upon to do so, I could and would testify to the following facts.

2.    I reside in Palo Alto, CA and have a mailing address of 502 Palm Ave., Los Altos California, 94022.

3.    I am the sole inventor of the subject matter disclosed and claimed in the above-identified United States Patent Application 10/610,960 ("the '960 Application").

Attorney Docket: STAN.P0010C
PTO Serial Number: 10/610,960

4. In the Office Action of June 26, 2008, the Examiner cited United States Patent 6,144,875 (the '875 patent) together with United States patent 5,299,288 as rendering obvious claims 10-21 of the '960 Application.

5. The '875 patent has a filing date of March 16, 1999. It does not claim the benefit of any earlier application. Accordingly, the earliest priority date of the '875 patent is March 16, 1999.

6. The '960 Application is a Continuation of United States Patent Application 09/792,485, filed on February 23, 2001. United States Patent Application 09/792,485 claims priority from Provisional Application 60/185,036, filed on February 25, 2000. Accordingly, the earliest priority date of the '960 application is February 25, 2000.

7. Independent claim 10 of the '960 Application recites (1) a method for maintaining a trajectory of a tracked first instrument (2) toward a target site in a human patient (3) as the tracked first instrument is moved in space toward the target site in the patient. The method uses (4) an image capture second instrument to construct an image of the target site that is defined by reference to (5) an image coordinate system. The method (6) correlates the image coordinate system with an instrument coordinate system to place a target site coordinate in the instrument coordinate system. The method (7) determines whether the target site has moved off the tracked first instrument's trajectory towards the target site. After determining that the target site has moved off the tracked first instrument's trajectory towards the target site, the method (8) computes a correction to the orientation of the tracked first instrument to re-orient the tracked first instrument towards the target site. The method (9) uses the computed correction to correct the orientation of the tracked first instrument to (10) maintain the

tracked first instrument's defined trajectory towards the target site even as the tracked first instrument is moved in space. Claims 11-13 are dependent directly or indirectly on Claim 10.

8.    Independent claim 14 of the '960 Application recites a computer readable medium version of the method disclosed in Claim 10. Claims 15-17 and 25 are dependent directly or indirectly on claim 14.

9.    Independent claim 18 of the '960 Application recites (1) a device for maintaining a trajectory between a tip of a tracked first instrument and a target site in a patient's body. The device has (2) an articulated mechanical arm with a tracked first instrument with a tip that has or (3) accommodates a force contact sensor. The device has (4) an actuator operatively connected to the mechanical arm for adjusting the orientation of the mechanical arm, so as to maintain the trajectory between the tip of the tracked first instrument and the target site in the patient's body. The device has (5) a tracking mechanism for tracking the orientation of the tracked first instrument in an instrument coordinate system. The device also has (6) a processor operatively connected to the actuator and tracking mechanism. The processor is for (7) using an image capture second instrument to construct an image of the target site that is defined by reference to the image coordinate system; (8) correlating the image coordinate system with an instrument coordinate system to place the target site coordinate in the instrument coordinate system; (9) determining whether the target site has moved off the tracked first instrument's trajectory towards the target site; (10) after determining that the target site has moved off the tracked first instrument's trajectory towards the target site, computing a correction to the orientation of the tracked first instrument to re-

orient the tracked first instrument towards the target site; and (11) using the computed correction to correct the orientation of the tracked first instrument to maintain the tracked first instrument's defined trajectory toward the target site even as the tracked first instrument is moved in space outside or inside the body.

10.     I hereby state that I conceived inventions that each comprised all of the individual elements and limitations of claims 10, 14, and 18, before March 16, 1999 and diligently worked to reduce the inventions to practice until the filing date of the '960 Application. This conception took place in the United States. My conception of the invention is demonstrated by the evidence described below and attached hereto.

11.     I conceived the inventions claimed in claims 10-21 before the earliest priority date of the '875 patent.

12.     Attached as Exhibit A, are photocopies of pages 41-51 of an original lab notebook dated from October 16, 1998 to December 4, 1998. The pages show that the conception of the inventions took place before March 16, 1999. Multiple copies of some pages are included to insure that no important information was cut off at the edges of the pages.

13.     The lab notebook is the notebook of my graduate student, at the time, Marc Epitaux. Marc worked for me until December 04, 1998, as indicated on page 51 of the lab notebook.

14.     The notebook records descriptions of my invention that I dictated to Marc Epitaux.

15.     The notes were written on the dates indicated on the individual pages and, as indicated on page 51 of the notebook, there were no blank pages of the notebook.

16. Other than page 49, all of the pages are signed and dated at the bottom by Marc Epitaux.

17. Page 51 is signed and dated by myself, Dr. Bai Wang, and Marc Epitaux.

18. The following paragraphs provide examples from the lab notebook that indicate that various limitations had been conceived before March 16, 1999. The page numbers refer to page numbers of the notebook.

19. The notebook's support for the conception of the method recited in claim 10 is described below in paragraphs 20-28.

20. The notebook supports the limitation of claim 10 of maintaining a trajectory of an instrument. For example, on page 50, the notebook recites a robot for "medical guidance". The illustration of a robot arm and a stick figure of a human on page 43 also supports this limitation.

21. The notebook supports the limitation of claim 10 of a target site in a human patient For example, on page 43, the computer code recites "patient.pts".

22. The notebook supports the limitation of claim 10 of the instrument moving in space. For example, pages 42 and 43 show movable joints for the movable robot arm.

23. The notebook supports the limitation of claim 10 of an image capture second instrument to construct an image of the target site. For example, page 43 illustrates an OTS (optical tracking system) and the computer code shows that the OTS is related to the patient.pts.

24. The notebook supports the limitation of claim 10 of an image coordinate system. For example, the computer code on page 43 recites coordinates of the OTS system (i.e., xOTS, yOTS, zOTS).

25. The notebook supports the limitation of claim 10 of correlating an image coordinate system with an instrument coordinate system. For example, the computer code on pages 43 et seq. and the figures on pages 46-47 show measurements of differences between coordinates of the instrument coordinate system and the coordinates of the image capture coordinate system.

26. The notebook supports the limitations of claim 10 of determining whether the target site has moved off the tracked first instrument's trajectory toward the target site, computing a correction to correct the orientation of the tracked first instrument and maintaining the tracked first instrument's defined trajectory toward the target site even as the tracked first instrument is moved in space. For example, page 50 recites medical guidance and the computer code recites calculations relating to both coordinate systems. Furthermore, page 49 illustrates rotations of the tip and an emitter coordinate for the tip position and as described above, the notebook also shows the correlation of the coordinate systems of the OTS and the emitter.

27. The notebook's support for the conception of the computer readable medium recited in claim 14 is listed in this paragraph. Claim 14 is a computer readable medium claim with similar limitations to claim 10. The notebook supports the limitation of claim 14 of a computer program stored on a computer readable medium. For example, the notebook shows computer code on pages 43 et seq. Also, the descriptions of the device on page 50 refer to "computer control". The notebook supports the limitations of claim 14 that correspond to limitations found in claim 10 in the same pages described in the preceding paragraphs.

28.  The notebook's support for the conception of the device recited in claim 18 is described below in paragraphs 29-37.

29.  The notebook supports the limitation of claim 18 of a device for maintaining a trajectory between a tip of a tracked first instrument and a target site in a human body. For example, on page 43, the notebook illustrates a robotic arm and the computer code recites "patient.pts". Furthermore, on page 50, the robot is described as being for "medical guidance".

30.  The notebook supports the limitation of claim 18 of an articulated mechanical arm. For example, the illustration of a robot arm on page 43 and the illustrations of the joints on pages 42 and 43 support the limitation of an articulated mechanical arm.

31.  The notebook supports the limitation of claim 18 of a force contact sensor. For example, on page 50, the notebook recites force measurement as part of the described device.

32.  The notebook supports the limitation of claim 18 of actuators operatively connected to the mechanical arm for adjusting the orientation of the mechanical arm so as to maintain the trajectory between the tip of the instrument and the target site in the patient's body. For example, the joints of the mechanical arm illustrated on page 42 and 43 have labeled illustrations of actuators.

33.  The notebook supports the limitation of claim 18 of a tracking mechanism for tracking the orientation of the tracked first instrument in an instrument coordinate system. For example, page 49 illustrates rotations and an emitter coordinate for a tip position.

34. The notebook supports the limitation of claim 18 of a processor operatively connected to the actuator and tracking mechanism. For example, on page 50, the robot is described as having computer control. Computers have processors.

35. The notebook supports the limitation of claim 18 of using an image capture second instrument to construct an image of the target site that is defined by reference to the image coordinate system. For example, the notebook shows an optical tracking system (OTS) on page 43.

36. The notebook supports the limitation of claim 18 of correlating the image coordinate system with an instrument coordinate system. For example, the computer code and figures of pages 46-47 show measurements of differences between coordinates of the instrument coordinate system and the coordinates of the image capture coordinate system.

37. The notebook supports the limitations of claim 18 of determining whether the target site has moved off the tracked first instrument's trajectory towards the target site, after determining that the target site has moved off the tracked first instrument's trajectory towards the target site, computing a correction to the orientation of the tracked first instrument to re-orient the tracked first instrument towards the target site; and using the computed correction to correct the orientation of the tracked first instrument to maintain the tracked first instrument's defined trajectory toward the target site even as the tracked first instrument is moved in space outside or inside the body. For example, page 50 recites medical guidance, the computer code recites calculations relating to both coordinate systems. Furthermore, page 49 illustrates rotations of the tip and an emitter coordinate for the tip position and as described

above, the notebook also shows the correlation of the coordinate systems of the OTS and the emitter.

38.    From before March 16, 1999 until the filing of the application, I and my graduate students worked diligently to reduce the robotic arm for maintaining the trajectory of the tracked first instrument and the image capture second instrument to practice, along with the other elements of the claims. We worked to reduce the claimed inventions to actual practice from at least January of 1999 until after Provisional Application 60/185,036 was filed on February 25, 2000.

39.    During the period from March 15, 1999 until the Provisional Application 60/185,036 was filed on February 25, 2000, I and/or my non-inventive research students worked every day on reducing the robotic arm for maintaining the trajectory of the tracked first instrument, the image capture second instrument, and the other limitations of the claims to practice, barring days in which daily job demands precluded work on the inventions and some weekends.

40.    Attached to this declaration as exhibits are a VHS video tape, a DVD copy of the video tape, and screenshots of the video that show the robot arm that my graduate students and I worked diligently to reduce to actual practice from at least January 1999 to after February 25, 2000.

41.    The filming of the video, and the described acts showing diligence in reducing the invention to practice all took place in the United States.

42.    Attached as Exhibit B is the VHS tape copy of the original digital video showing part of the attempts to reduce the robotic arm for maintaining the trajectory of the tracked first instrument and the image capture second instrument to practice.

43.    Attached as Exhibit C is a DVD copy of the same video.

44.    The video shows our work on the robotic arm that maintains trajectory of the tracked instrument and an image capture second instrument. In the video the trajectory is maintained toward a target (a green ball) in a model of a human skull.

45.    Attached as Exhibit D is a screen capture of the video, showing the robotic arm tracking an object inside a model of a human skull.

46.    Attached as Exhibit E is a screen capture of the video showing an optical tracking system. The optical tracking system is labeled "OTS". The label "OTS" was added subsequent to the creation of the image for identification purposes and was not in the video.

47.    At the time that the video of Exhibits B-E was shot, I was an Assistant Professor of neurosurgery at Stanford University. The video shows graduate students, Jacqueline Welch, Clement Yeh, and Mohammad Sadeghi, as well as consulting senior research assistants Rasool Khadem and Diego Ruspini.

48.    Mohammad Sadeghi is the person who is mainly conducting the demo in the video of Exhibits B-E. Exhibits B and C show a robotic arm implementing most of the elements of claims 10, 14, and 18 by maintaining a trajectory of a tracked first instrument toward a target site as the tracked first instrument is moved in space toward the target site. The video shows that the machine determines whether the target site has moved off the tracked first instrument's trajectory towards the target site. After determining that the target site has moved off the tracked first instrument's trajectory towards the target site, the machine computes a correction to the orientation of the tracked first instrument to re-orient the tracked first instrument towards the

target site. The machine uses the computed correction to correct the orientation of the tracked first instrument to maintain the tracked first instrument's defined trajectory towards the target site even as the tracked first instrument is moved in space. At this point, as shown in the video, the elements of registration, tracking and reorienting by the robot had been reduced to practice. However, at the time of the video the robot had not been used on a human patient. We were trying to reduce that aspect of the invention to practice, as shown by the use of physical models of human anatomy, such as the clear model of a human skull shown in the video.

49. The limitation of using the machine on a human patient was a limitation that we were working on reducing to practice. We were still diligently working on actually reducing the invention to practice on the filing date of the Provisional Application 60/185,036, February 25, 2000, when the inventions were constructively reduced to practice.

50. The exact date on which the video was shot is currently unknown as we were working on reducing the robotic arm for maintaining the trajectory of the tracked first instrument and the image capture second instrument to practice over a period from before March 16, 1999 until after February 25, 2000. However, I have determined a range of possible dates for the video, based on the dates during which Mohammad Sadeghi was employed at the lab.

51. Mohammad Sadeghi is a graduate student who was hired for the sole purpose of reducing to practice the concepts described in Marc Epitaux's Lab-Note-book pages dated November 1998.
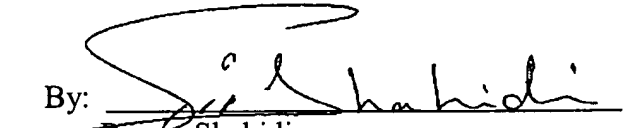
52. Mohammad Sadeghi joined our research group in January, 1999 and left our group in September, 1999.

53. Mohammad Sadeghi could only have been in the video during the time that he was at the lab. Accordingly, the earliest possible date for the video is January 1999 and the latest possible date for the video is September, 1999. We were working on reducing the robotic arm and the optical system and other elements of the claimed inventions to practice over that entire period and beyond, continuing past the February 25, 2000 filing date of Provisional Application 60/185,036.

54. The following paragraphs describe other efforts that I made in furtherance of reducing the robotic arm for maintaining the trajectory of the tracked first instrument, the image capture second instrument, and the other limitations of the claims to practice.

55. During the period between November 1998 and September 1999, I have had one full time graduate student dedicated his research studies toward the reduction of the claimed inventions to practice.

56. During the time period from March 15, 1999 to February 25, 2000, I had several other graduate students on part-time basis, as well as two other senior research consultants, working toward reducing the claimed inventions to practice.

57. I formed a corporation, CBYON, INC.

58. A specific motivation for forming CBYON, INC. was to reduce to practice the robotic arm for maintaining the trajectory of the tracked first instrument, the image capture second instrument, and the other limitations of claims 10-21.

59. The documents of incorporation of CBYON, INC. were filed with the California Secretary of State on January 6, 1999. This is shown on the attached Exhibit F, a

printout of information from the website of the California Secretary of State that shows the date of filing of the documents of incorporation.

60. The company continued in business until after the February 25, 2000 filing date of the Provisional Application 60/185,036.

61. In the course of the operation of the company, we researched reduction to practice of the invention, including elements of the claim that go beyond the details explicitly shown in the video (e.g., use on actual human patients). For example, at CBYON, INC. we experimented with patient-specific imaging systems, correlating coordinates in an image coordinate system and an instrument coordinate system, and tracking targets in a human patient.

62. Our work to reduce the invention to practice included efforts to acquire necessary parts such as the optical tracking system, individual tracking diode-based markers and a Robotic Arm, as well as efforts to code the necessary software, the methods for calibration of the system, the design of validation and feasibility algorithms, thinking of ways to implement the human/machine interface in such a way as to practice the claimed inventions, and efforts for system integration in such a way as to practice the claimed inventions.

63. I hired Patent Attorney Peter Jean Dehlinger, USPTO registration number 28006, to draft and file the application in April of 1999. While he worked on drafting the patent application, I and my non-inventive research assistants continued to work on reducing the invention to practice.

64. All statements made herein are true and based on my own knowledge or believed to be true based upon information and belief. I understand that willful false statements and the like are punishable by a fine or imprisonment or both pursuant to 18 USC § 1001. Any willfully false statements may jeopardize the validity of the application or any patent issuing thereon.


Dated: _____12-29-2008_____      By: _____
                                                            Ramin Shahidi

**EXHIBIT A**

Photocopies of pages 41-51 of an original lab notebook dated from October 16, 1998 to

December 4, 1998. Multiple copies of pages 43-51 are included to provide complete views of the

pages.

# LABORATORY NOTEBOOK PROCEDURE

RAMIN- 498-40

LAB - 498- 41

FAX - 723-75

STANFORD UNIV
of ME
Dept. of Neuro
300 Pasteur D
Room R164 MC;
STANFORD CA
94305-

EMERGENCY
Pager. 607-2397
Ramin

222 -> 394
498-4145

This notebook is designed to be of maximum usefulness to faculty and research staff in the laboratory and, at the same time, meet the patent requirements of U.S. Government and other agencies sponsoring research at Stanford. It should be used for recording all ideas, design information, construction details, test results, etc., associated with the project for which it is issued. Since it will serve as part of the history of the project for both technical and legal purposes, entries should be unambiguous as to context and date.

Adequate titles and headings, diagrams, sketches, and explanatory notes should be used. The table of contents at the beginning of the notebook should be kept up to date.

All entries should be in ink, and mistakes crossed out rather than erased. Unused portions of pages should be crossed with a single diagonal line. Essential loose material, such as photographs or graphs, should be permanently pasted in.

Each page should be dated and initialed by the individual making the entry, and the notebook should be checked and signed periodically by the project director.

Ideas thought patentable should be recorded in detail and witnessed by someone (other than a co-inventor) who has read and understood the entry and indicates this next to his signature. The Research Administrator should then be notified.

Notebooks disclosing inventions which contain patentable ideas must be retained in the University until disposition of any patent rights therein.

It should be noted that the University's grant and contract obligations, as well as good notebook practice, require attention to these details.

Notebook No. _1_   MARC   Classification _HUMAN) WARE INTERFACE PROJECT - GENESIS-_

Issued to _MARC L. PILAUX_   Date _April 1st, 98_

Contract or Grant _Internal Department Funding_

Project _GENESIS - Volumetric Image Navigation_

Project Director _Ramin SHAHIDI_

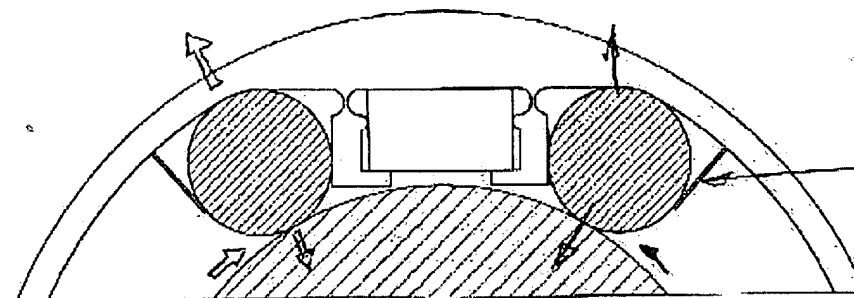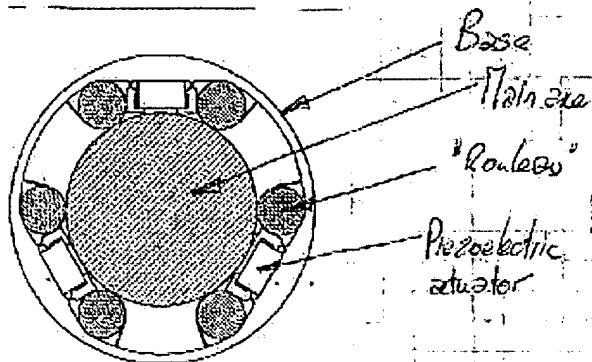Associated Notebooks _Note Book #1 by BAI WANG-_

Returned to File ..............................................................................

Checked for Patentable Inventions ..............................................................................

# BRAKES FOR DYNAMICS CONSTRAINT
## JOINTS (system de roue libre)

Base

Main axe

"Rouleau"

Piezoelectric
actuator

elastic beam

Piezoelectric actuator

*Electromagnet control*

*"butée*

## OTS Linearity                    11/3/98



ate Puma

OTS Flash Point 500

Radionic Tool Radodl

isition 120 x 2 points

OTS axis Z

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*vol_linear.nb*

```
In[1]:=  << Graphics`Graphics`
         << Graphics`Graphics3D`
         << Graphics`PlotField3D`


Out[2]= Null²
```

liner_OTS –> patient.pts
liner_robot –>recimg.pts

```
In[23]:=  datalistOTS = ReadList["liner_OTS.txt"];
          dataOTS = Part[datalistOTS, 1];
          datatranspOTS = Transpose[dataOTS];
          xOTS = Part[datatranspOTS, 1];
          yOTS = Part[datatranspOTS, 2];
          zOTS = Part[datatranspOTS, 3];

          NumberOfPoints
          numberpts = Count[Part[datatranspOTS, 1], _Real]

          datalistrobot = ReadList["liner_robot.txt"];
          datarobot = Part[datalistrobot, 1];
          datatransprobot = Transpose[datarobot];
          xrobot = Part[datatransprobot, 1];
          yrobot = Part[datatransprobot, 2];
          zrobot = Part[datatransprobot, 3];

Out[23]= NumberOfPoints
```
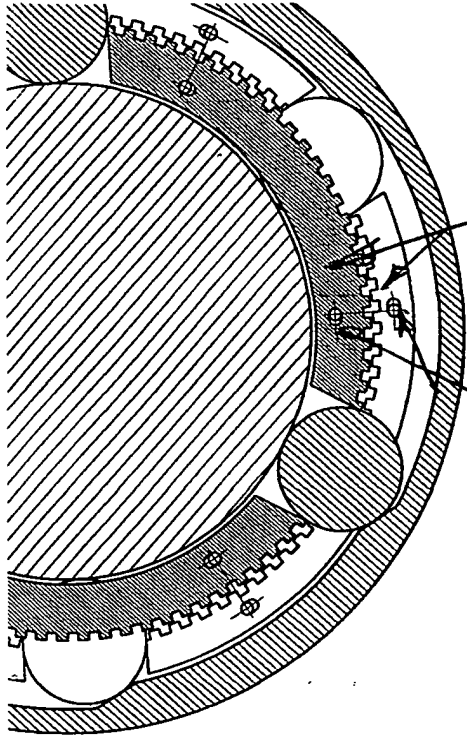
Electromagnet coils

"butée"

## OTS Linearity

11/3/98



Robot
Unimate Puma
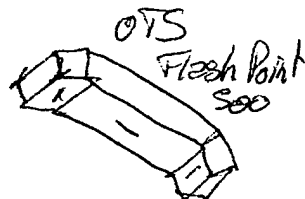
OTS
Flash Point
500

Radionic Tool
Radodl

Acquisition 120 x 2 points
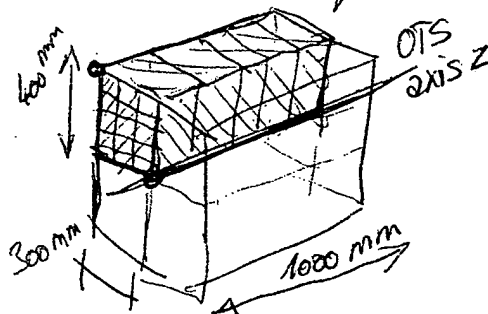
600 mm
300 mm
1000 mm

OTS
axis Z

*vol_linear.nb*

```
In[1]:=  << Graphics`Graphics`
         << Graphics`Graphics3D`
         << Graphics`PlotField3D`

Out[2]= Null²
```

liner_OTS –> patient.pts
liner_robot –>recimg.pts

```
In[23]:=  datalistOTS = ReadList["liner_OTS.txt"];
          dataOTS = Part[datalistOTS, 1];
          datatranspOTS = Transpose[dataOTS];
          xOTS = Part[datatranspOTS, 1];
          yOTS = Part[datatranspOTS, 2];
          zOTS = Part[datatranspOTS, 3];

          NumberOfPoints
          numberpts = Count[Part[datatranspOTS, 1], _

          datalistrobot = ReadList["liner_robot.txt"
          datarobot = Part[datalistrobot, 1];
          datatransprobot = Transpose[datarobot];
          xrobot = Part[datatransprobot, 1];
          yrobot = Part[datatransprobot, 2];
          zrobot = Part[datatransprobot, 3];

Out[23]= NumberOfPoints

Out[24]= 120
```

Signed................................................Date........

Electromagnet control

"butée

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## Linearity

<span style="float:right">11/3/98</span>

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OTS
Flesh Point
500

~ Radionic Tool
Redocl/

x 2 points

OTS
axis z

1000 mm

**vol_linear.nb**

---

```
In[1]:=  << Graphics`Graphics`
         << Graphics`Graphics3D`
         << Graphics`PlotField3D`
```

```
Out[2]= Null²
```

liner_OTS –> patient.pts
liner_robot –>recimg.pts

```
In[23]:=  datalistOTS = ReadList["liner_OTS.txt"];
          dataOTS = Part[datalistOTS, 1];
          datatranspOTS = Transpose[dataOTS];
          xOTS = Part[datatranspOTS, 1];
          yOTS = Part[datatranspOTS, 2];
          zOTS = Part[datatranspOTS, 3];

          NumberOfPoints
          numberpts = Count[Part[datatranspOTS, 1], _Real]

          datalistrobot = ReadList["liner_robot.txt"];
          datarobot = Part[datalistrobot, 1];
          datatransprobot = Transpose[datarobot];
          xrobot = Part[datatransprobot, 1];
          yrobot = Part[datatransprobot, 2];
          zrobot = Part[datatransprobot, 3];
```

```
Out[23]= NumberOfPoints
```

```
Out[24]= 120
```

Signed ............................................ Date ...11/25/98

```mathematica
In[123]:= Mat = {{0.075142, 0.069225, 0.970540},
        {-0.977741, -0.001229, -0.018088},
        {-0.187500, -0.973961, -0.051476}};

        Vect = {1651.152460, 275.324422, -233.030664};


        OrigRobot = (Part[Part[datalistrobot, 1], 1] + Part[Part[datalistrobot, 1], 101]) / 2;
        uRobot = Part[Part[datalistrobot, 1], 1] - Part[Part[datalistrobot, 1], 101];

        uRobot = uRobot / Sqrt[Part[uRobot, 1]^2 + Part[uRobot, 2]^2 + Part[uRobot, 3]^2];

        PRobot = (Part[Part[datalistrobot, 1], 16] + Part[Part[datalistrobot, 1], 116]) / 2;
        q = PRobot . uRobot;
        vRobot = PRobot - q * uRobot;

        vRobot = -vRobot / Sqrt[Part[vRobot, 1]^2 + Part[vRobot, 2]^2 + Part[vRobot, 3]^2];

        wRobot = Cross[uRobot, vRobot];

        wRobot = wRobot / Sqrt[Part[wRobot, 1]^2 + Part[wRobot, 2]^2 + Part[wRobot, 3]^2];


        OrigOTS = (Part[Part[datalistOTS, 1], 1] + Part[Part[datalistOTS, 1], 101]) / 2;
        uuOTS = Part[Part[datalistOTS, 1], 1] - Part[Part[datalistOTS, 1], 101];

        uuOTS = uuOTS / Sqrt[Part[uuOTS, 1]^2 + Part[uuOTS, 2]^2 + Part[uuOTS, 3]^2];

        POTS = (Part[Part[datalistOTS, 1], 5] + Part[Part[datalistOTS, 1], 105]) / 2;
        p = POTS . uuOTS;
        vvOTS = POTS - p * uuOTS;

        vvOTS = vvOTS / Sqrt[Part[vvOTS, 1]^2 + Part[vvOTS, 2]^2 + Part[vvOTS, 3]^2];

        wwOTS = Cross[uuOTS, vvOTS];

        wwOTS = wwOTS / Sqrt[Part[wwOTS, 1]^2 + Part[wwOTS, 2]^2 + Part[wwOTS, 3]^2];

        MRobot = {uRobot, vRobot, wRobot};
        MOTS = {uuOTS, vvOTS, wwOTS};

        M = Inverse[MRobot] . MOTS
        Det[M]

Out[123]= {{-0.015728, 0.0367667, 0.9992}, {-0.999057, 0.039875, -0.017193},
        {-0.0404752, -0.998528, 0.0361048}}

Out[124]= 1.

In[125]:= datalisttrans = {0};
        For[i = 1, i < numberpts + 1, i++, datalisttrans =
          Append[datalisttrans, M . (Part[Part[datalistOTS, 1], i] - OrigOTS) + OrigRobot]]
        datalisttrans = Delete[datalisttrans, 1];
        datatransptrans = Transpose[datalisttrans];
        xtrans = Part[datatransptrans, 1];
        ytrans = Part[datatransptrans, 2];
        ztrans = Part[datatransptrans, 3];

        datatransptrans = {xtrans, ytrans, ztrans};
        datalisttrans = {Transpose[datatransptrans]};

        ampl = 3;
        field = {0};
        error = {0};
        For[i = 1, i < numberpts, i++,
          field = Append[field, {Part[Part[datalistrobot, 1], i],
            ampl (Part[Part[datalisttrans, 1], i] - Part[Part[datalistrobot, 1], i])}];
          VectPos = Part[Part[datalistrobot, 1], i] - OrigRobot;
```

```
Robot = (Part[Part[datalistrobot, 1], 1] + Part[Part[datalistrobot, 1], 101]) / 2;
)t = Part[Part[datalistrobot, 1], 1] - Part[Part[datalistrobot, 1], 101];

)t = uRobot / sqrt(Part[uRobot, 1]^2 + Part[uRobot, 2]^2 + Part[uRobot, 3]^2);

)t = (Part[Part[datalistrobot, 1], 16] + Part[Part[datalistrobot, 1], 116]) / 2;
lobot . uRobot;
)t = PRobot - q * uRobot;

)t = -vRobot / sqrt(Part[vRobot, 1]^2 + Part[vRobot, 2]^2 + Part[vRobot, 3]^2);

)t = Cross[uRobot, vRobot];

)t = wRobot / sqrt(Part[wRobot, 1]^2 + Part[wRobot, 2]^2 + Part[wRobot, 3]^2);


TS = (Part[Part[datalistOTS, 1], 1] + Part[Part[datalistOTS, 1], 101]) / 2;
 = Part[Part[datalistOTS, 1], 1] - Part[Part[datalistOTS, 1], 101];

 = uuOTS / sqrt(Part[uuOTS, 1]^2 + Part[uuOTS, 2]^2 + Part[uuOTS, 3]^2);

= (Part[Part[datalistOTS, 1], 5] + Part[Part[datalistOTS, 1], 105]) / 2;
TS . uuOTS;
 = POTS - p * uuOTS;


 = vvOTS / sqrt(Part[vvOTS, 1]^2 + Part[vvOTS, 2]^2 + Part[vvOTS, 3]^2);

 = Cross[uuOTS, vvOTS];

 = wwOTS / sqrt(Part[wwOTS, 1]^2 + Part[wwOTS, 2]^2 + Part[wwOTS, 3]^2);


:= {uRobot, vRobot, wRobot};
 {uuOTS, vvOTS, wwOTS};

rerse[MRobot] . MOTS


)15728, 0.0367667, 0.9992}, {-0.999057, 0.039875, -0.017193},
)404752, -0.998528, 0.0361048}}



sttrans = {0};
: 1, i < numberpts + 1, i++, datalisttrans =
nd[datalisttrans, M . (Part[Part[datalistOTS, 1], i] - OrigOTS) + OrigRobot]]
sttrans = Delete[datalisttrans, 1];
ansptrans = Transpose[datalisttrans];
 = Part[datatransptrans, 1];
 = Part[datatransptrans, 2];
 = Part[datatransptrans, 3];

ansptrans = {xtrans, ytrans, ztrans};
sttrans = {Transpose[datatransptrans]};

 3;
: {0};
= {0};
: 1, i < numberpts, i++,
 = Append[field, {Part[Part[datalistrobot, 1], i],
pl (Part[Part[datalisttrans, 1], i] - Part[Part[datalistrobot, 1], i])}];
os = Part[Part[datalistrobot, 1], i] - OrigRobot;
```

Signed ...~~[signature]~~... Date ...11/25/8..

```mathematica
    Vecterror = (Part[Part[datalisttrans, 1], i] - Part[Part[datalistrobot, 1], i]);
    error = Append[error, {√(Part[VectPos, 2]² + Part[VectPos, 3]²) ,
       √(Part[Vecterror, 1]² + Part[Vecterror, 2]² + Part[Vecterror, 3]²) }];
    ]
    field = Append[field, {OrigRobot + {0, 0, 0}, {100, 0, 0}}];
    field = Append[field, {OrigRobot + {0, 0, 0}, {0, 100, 0}}];
    field = Append[field, {OrigRobot + {0, 0, 0}, {0, 0, 100}}];
    field = Delete[field, 1];
    error = Delete[error, 1];


    grid = {0};
    For[j = 0, j < numberpts, j = j + i,
     For[i = 1, i < 5, i++,
        grid = Append[grid, {Part[Part[datalisttrans, 1], i + j],
          Part[Part[datalisttrans, 1], i + j + 1] - Part[Part[datalisttrans, 1], i + j]}]
      ]
    ]
    For[k = 0, k < numberpts, k = k + j + 5,
     For[j = 0, j < 15, j = j + i - 1,
      For[i = 1, i < 6, i++,
        grid = Append[grid, {Part[Part[datalisttrans, 1], i + j + k], Part[
            Part[datalisttrans, 1], i + j + k + 5] - Part[Part[datalisttrans, 1], i + j + k]}]
       ]
     ]
    ]
    For[j = 0, j < numberpts, j = j + i,
     For[i = 1, i < 5, i++,
        grid = Append[grid, {Part[Part[datalistrobot, 1], i + j],
          Part[Part[datalistrobot, 1], i + j + 1] - Part[Part[datalistrobot, 1], i + j]}]
      ]
    ]
    For[k = 0, k < numberpts, k = k + j + 5,
     For[j = 0, j < 15, j = j + i - 1,
      For[i = 1, i < 6, i++,
        grid = Append[grid, {Part[Part[datalistrobot, 1], i + j + k], Part[
            Part[datalistrobot, 1], i + j + k + 5] - Part[Part[datalistrobot, 1], i + j + k]}]
       ]
     ]
    ]
    grid = Append[grid, {OrigRobot + {0, 0, 0}, {100, 0, 0}}];
    grid = Append[grid, {OrigRobot + {0, 0, 0}, {0, 100, 0}}];
    grid = Append[grid, {OrigRobot + {0, 0, 0}, {0, 0, 100}}];
    grid = Delete[grid, 1];

    ListPlotVectorField3D[field, VectorHeads -> True, ViewPoint -> {0.974, 3.090, 0.975}]

    ListPlotVectorField3D[grid, ViewPoint -> {0.974, 3.090, 0.975}]

    diag = Part[Part[datalistOTS, 1], 1] - Part[Part[datalistOTS, 1], numberpts];
    DiagOTS ;
    √(Part[diag, 1]² + Part[diag, 2]² + Part[diag, 3]²) ;
    diag = Part[Part[datalistrobot, 1], 1] - Part[Part[datalistrobot, 1], numberpts];
    Diagrobot ;
    √(Part[diag, 1]² + Part[diag, 2]² + Part[diag, 3]²) ;
    diag = Part[Part[datalisttrans, 1], 1] - Part[Part[datalisttrans, 1], numberpts];
    Diagtrans ;
    √(Part[diag, 1]² + Part[diag, 2]² + Part[diag, 3]²) ;

    ListPlot[error]
```

```
j = Append[field, {OrigRobot + {0, 0, 0}, {100, 0, 0}}];
j = Append[field, {OrigRobot + {0, 0, 0}, {0, 100, 0}}];
j = Append[field, {OrigRobot + {0, 0, 0}, {0, 0, 100}}];
j = Delete[field, 1];
r = Delete[error, 1];


= {0};
j = 0, j < numberpts, j = j + i,
[i = 1, i < 5, i++,
rid = Append[grid, {Part[Part[datalisttrans, 1], i + j],
 Part[Part[datalisttrans, 1], i + j + 1] - Part[Part[datalisttrans, 1], i + j]}]


t = 0, k < numberpts, k = k + j + 5,
[j = 0, j < 15, j = j + i - 1,
:[i = 1, i < 6, i++,
rid = Append[grid, {Part[Part[datalisttrans, 1], i + j + k], Part[
    Part[datalisttrans, 1], i + j + k + 5] - Part[Part[datalisttrans, 1], i + j + k]}]


j = 0, j < numberpts, j = j + i,
:i = 1, i < 5, i++,
rid = Append[grid, {Part[Part[datalistrobot, 1], i + j],
 Part[Part[datalistrobot, 1], i + j + 1] - Part[Part[datalistrobot, 1], i + j]}]


t = 0, k < numberpts, k = k + j + 5,
[j = 0, j < 15, j = j + i - 1,
:[i = 1, i < 6, i++,
rid = Append[grid, {Part[Part[datalistrobot, 1], i + j + k], Part[
    Part[datalistrobot, 1], i + j + k + 5] - Part[Part[datalistrobot, 1], i + j + k]}]


= Append[grid, {OrigRobot + {0, 0, 0}, {100, 0, 0}}];
= Append[grid, {OrigRobot + {0, 0, 0}, {0, 100, 0}}];
= Append[grid, {OrigRobot + {0, 0, 0}, {0, 0, 100}}];
= Delete[grid, 1];

PlotVectorField3D[field, VectorHeads -> True, ViewPoint -> {0.974, 3.090, 0.975}]

PlotVectorField3D[grid, ViewPoint -> {0.974, 3.090, 0.975}]

= Part[Part[datalistOTS, 1], 1] - Part[Part[datalistOTS, 1], numberpts];
OTS ;
```

$t[diag, 1]^2 + Part[diag, 2]^2 + Part[diag, 3]^2 ;$

```
= Part[Part[datalistrobot, 1], 1] - Part[Part[datalistrobot, 1], numberpts];
robot ;
```

$t[diag, 1]^2 + Part[diag, 2]^2 + Part[diag, 3]^2 ;$

```
= Part[Part[datalisttrans, 1], 1] - Part[Part[datalisttrans, 1], numberpts];
trans ;
```

$t[diag, 1]^2 + Part[diag, 2]^2 + Part[diag, 3]^2 ;$

```
Plot[error]
```

OTS
main Axis
(z)
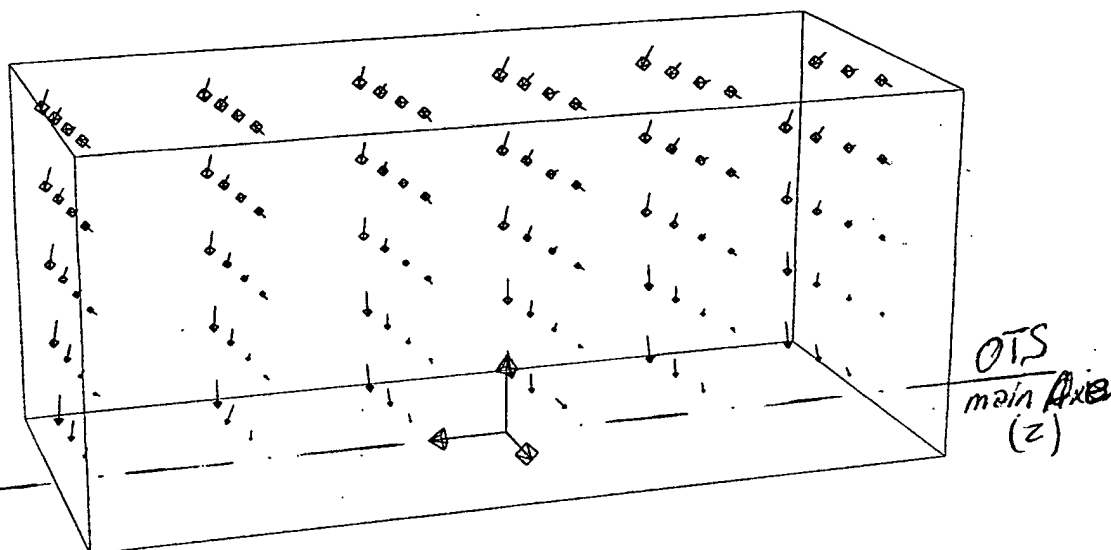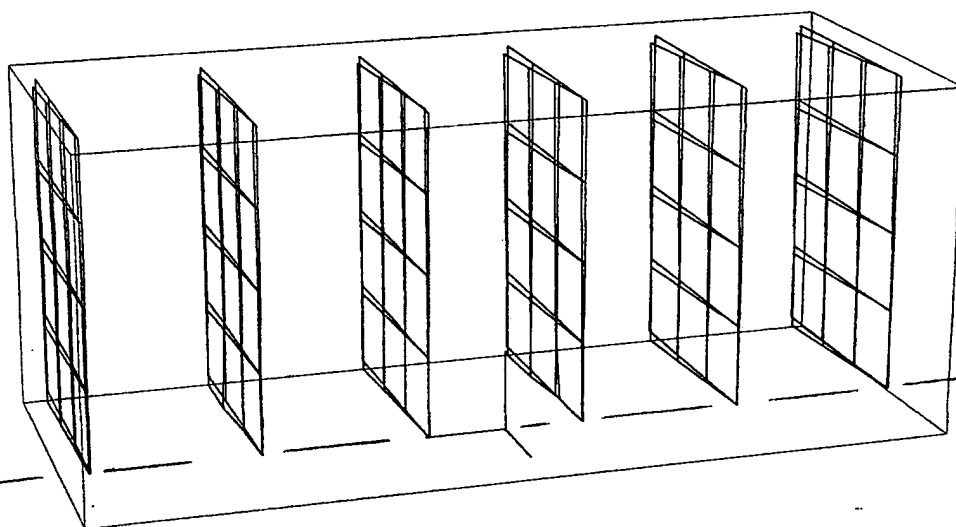
*Out[131]=* - Graphics3D -



*Out[132]=* - Graphics3D -
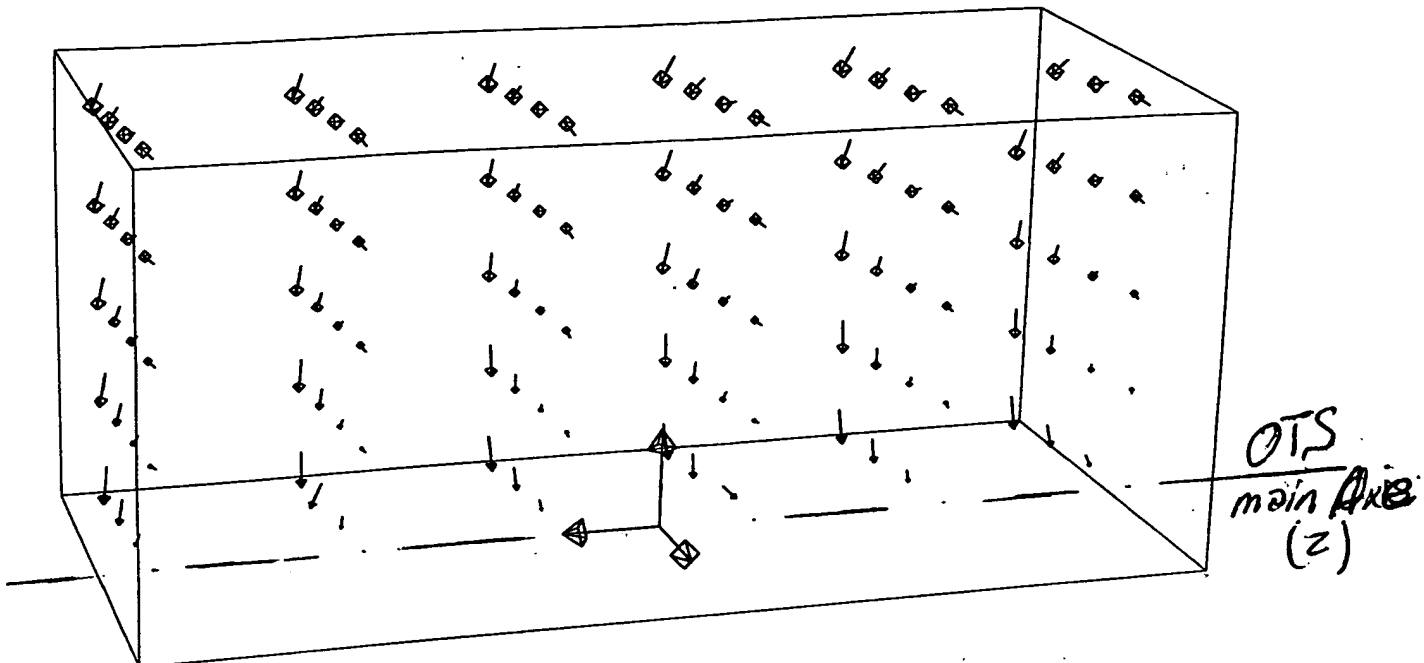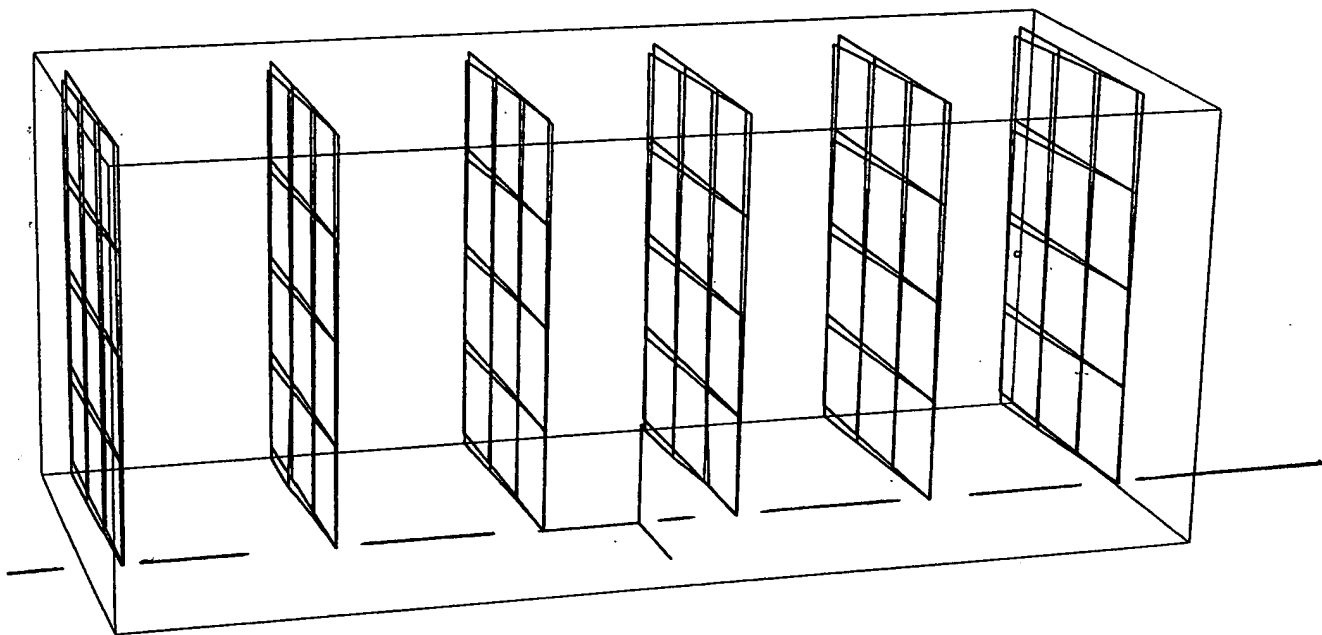
OTS
main Axis
(z)

*311=* - Graphics3D -



*21=* - Graphics3D -

Distance to [mm]
the main axe

Distance
to [mm]
the main axe
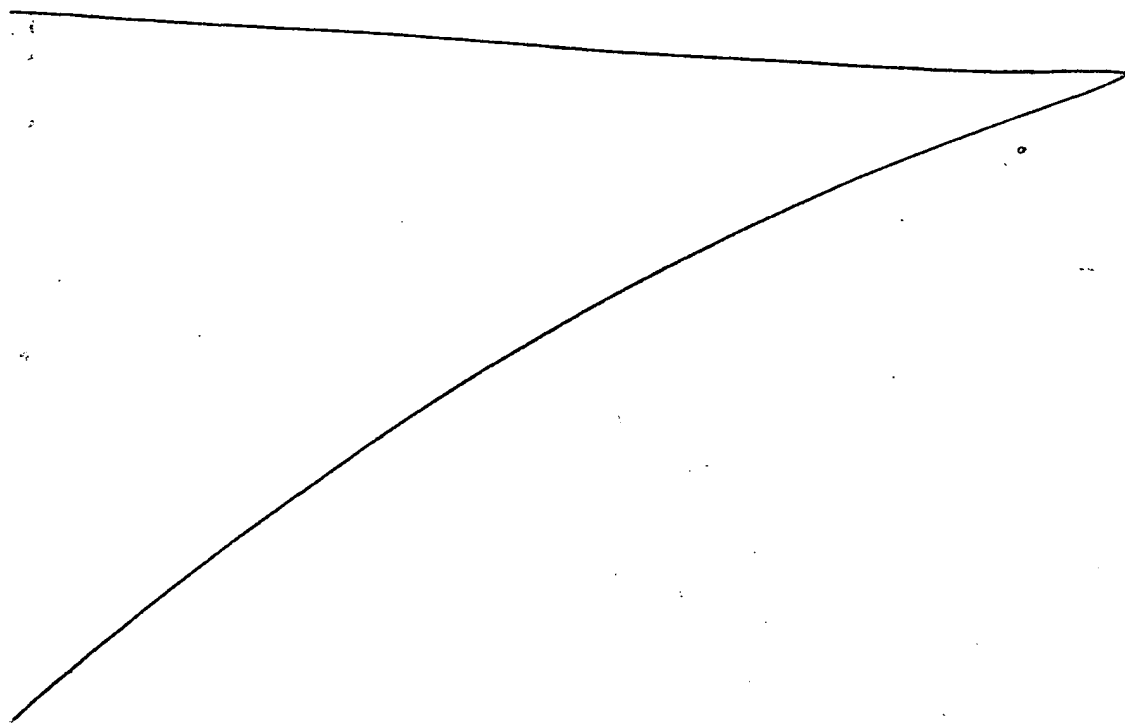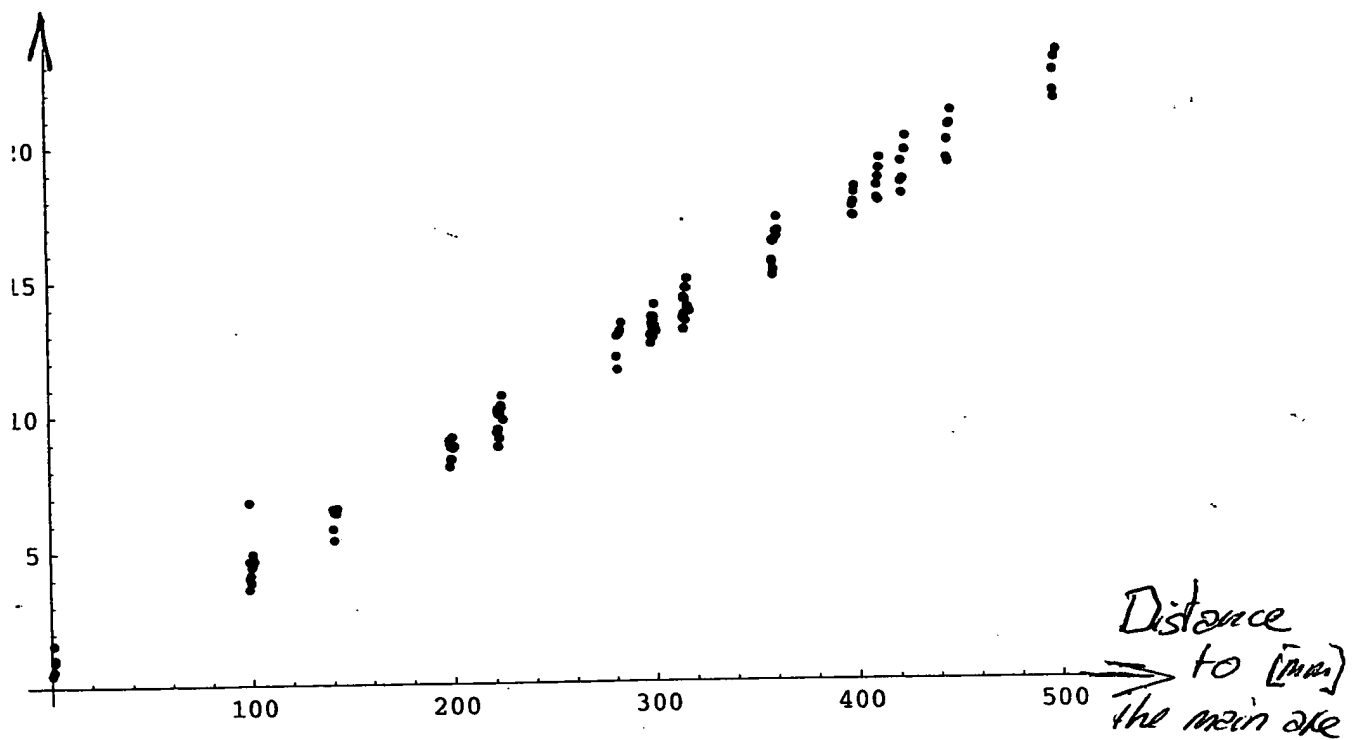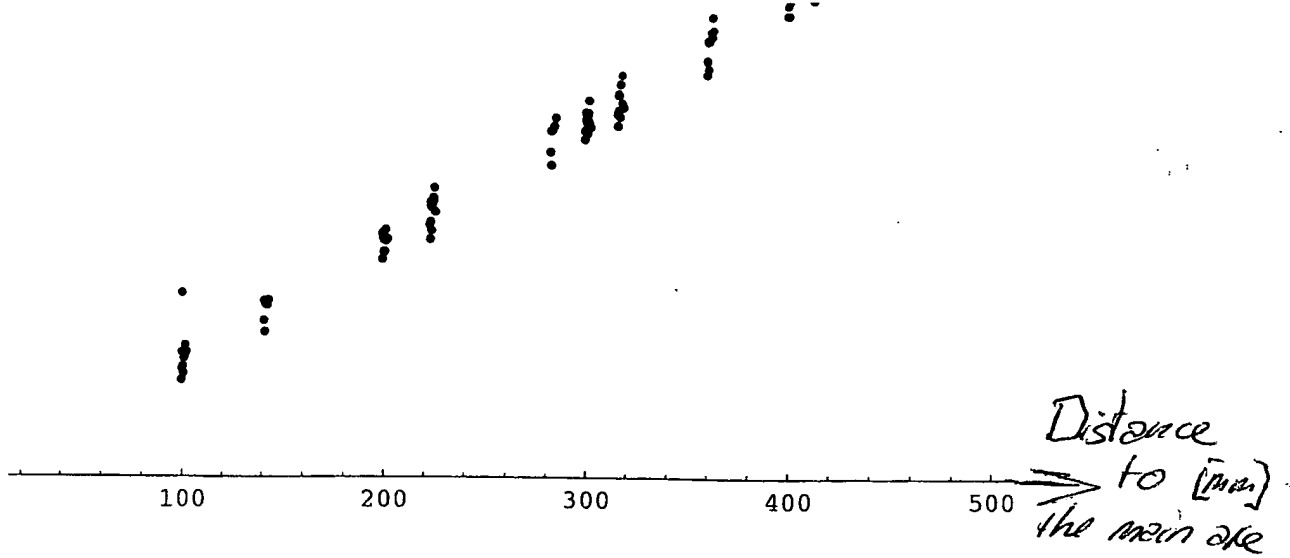
Signed ............................................ Date 11/28/98

*BRAKES For Dynamic Constraint-Joint Robot* 11/19/98

System for manipulating movement of a surgical instrument with computer controlled brake   United States Patent 5,695,500 Taylor, et. al. Dec. 9

System and method for augmentation of surgery   United States Patent 5,630,431 Taylor May 20, 1997

System and method for augmentation of surgery   United States Patent 5,402,801 Taylor Apr. 4, 1995

Signaling device and method for monitoring positions in a surgical operation   United States Patent 5,279,309 Taylor, et. al. Jan. 18, 1994

Computerized brake control system   United States Patent 4,402,047 Newton, et. al. Aug. 30, 1983

Braking system utilizing both a dynamic and a mechanical brake   United States Patent 4,278,298 Sauka, et. al. Jul. 14, 1981

Drive, particularly for an industrial manipulator   United States Patent 4,339,984 Huhne Jul. 20, 1982

Manipulator and control method   United States Patent   4,928,047 Arai, et. al. May 22, 1990 (dynamic constraint & kinematic)

*US patents*

JOURNAL OF MECHANICAL DESIGN-TRANSACTIONS OF THE ASME v. 104(#1) pp.29-38 1982 OPTIMIZATION OF CAM-FOLLOWER SYSTEMS WITH KINEMATIC AND DYNAMICCONSTRAINTS

PROCEEDINGS OF THE INSTITUTION OF MECHANICAL ENGINEERS PART  H-JOURNAL OF ENGINEERING IN MEDICINE v. 211(#4) pp. 285-292 1997  ACTIVE COMPLIANCE IN ROBOTIC SURGERY : THE USE OF FORCE CONTROL  AS A DYNAMIC CONSTRAINT

MECHATRONICS v. 6(#4) pp. 399-421 JUN 1996 IN- FAC MED,IAB,IMAG LAB,TIMC/F-38706 LA TRONCHE//FRANCE SEMIACTIVE GUIDING SYSTEMS IN SURGERY : A 2-DOF PROTOTYPE OF THE PASSIVE ARM WITH DYNAMIC CONSTRAINTS (PADYC)

JOURNAL OF ROBOTIC SYSTEMS v. 15(#3) pp. 115-129 MAR 1998 CARNEGIE MELLON UNIV,INST ROBOT/PITTSBURGH//PA/15213 OPTIMAL-CONTROL OF MANIPULATORS WITH ANY NUMBER OF PASSIVE JOINTS

ELECTRONICS LETTERS v. 34(#18) pp. 1796-1797 SEP 3, 1998 IN- KOREA ADV INST SCI & TECHNOL,DEPT ELECT ENGN,YUSONG GU,373-1 KUSONG DONG/TAEJON 305701 DYNAMICS AND ROBUST-CONTROL OF UNDERACTUATED MANIPULATORS USING BRAKES AT PASSIVE JOINTS

JOURNAL OF GUIDANCE CONTROL AND DYNAMICS v. 19(#5) pp. 1039-1046 SEP-OCT 1996 N CAROLINA STATE UNIV/RALEIGH//NC/27695  ROBUST-CONTROL OF PASSIVE-JOINTED ROBOT AND EXPERIMENTAL VALIDATION USING SLIDING MODE

IEEE TRANSACTIONS ON ROBOTICS AND AUTOMATION v. 7(#4) pp. 528-534   1991

IN- MINIST INT TRADE & IND,AGCY IND SCI & TECHNOL,DEPT ROBOT,MECH ENGN LAB,1-2 NAMIKI/TSUKUBA POSITION CONTROL OF A MANIPULATOR WITH PASSIVE JOINTS USING  DYNAMIC COUPLING

IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS v. 38(#1) pp. 15-20 1991 MINIST INT TRADE & IND,DEPT ROBOT,MECH ENGN LAB/TSUKUBA//JAPAN POSITION CONTROL-SYSTEM OF A 2-DEGREE OF FREEDOM MANIPULATOR  WITH A PASSIVE JOINT

*Publications*

System for manipulating movement of a surgical instrument with computer controlled brake   United States Patent 5,695,500 Taylor, et. al. Dec. 9

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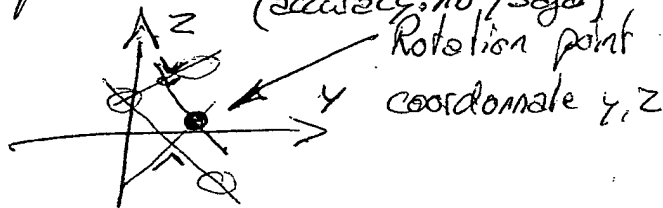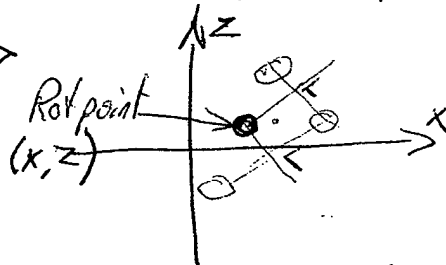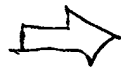
Signed_____ Da

# Tool calibration (RegTool)

4/28/98
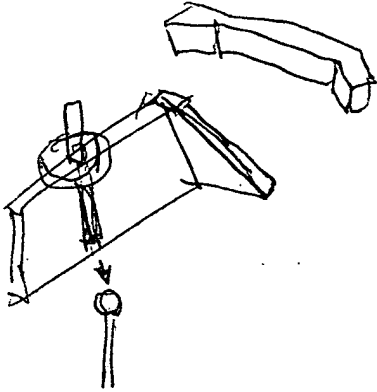
3 Phases:

- Rotation about x (3 positions!)
  data acquisition (-/accuracy -2§/02)
  (accuracy nb /sigo)

  ⇒ Rotation point
  coordonate y, z

- Rotation about y (3 positions!)

  ⇒ Rot point
  (x, z)

- Rotation about z (3 positions!)

  ⇒ Rotation point
  (x, y)

---
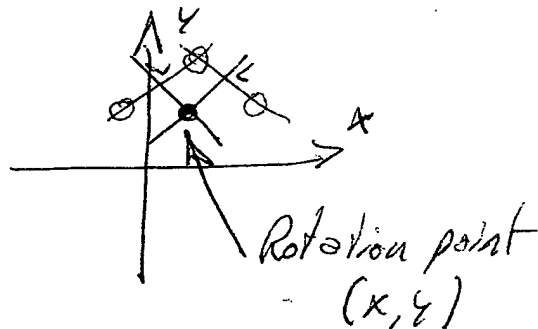
The 6 values should be redundant!
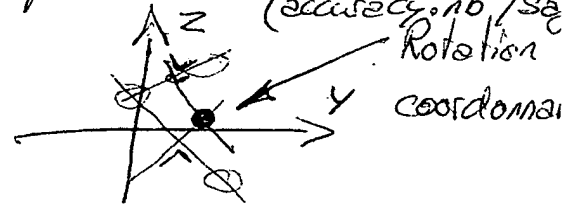
⇒ Rotation point

With the emitter coordinate ⇒
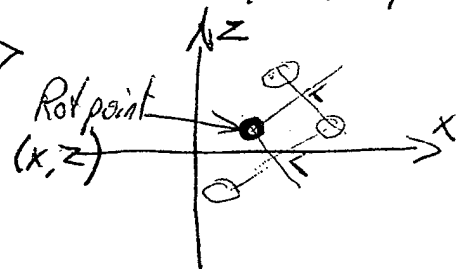
position from the description file
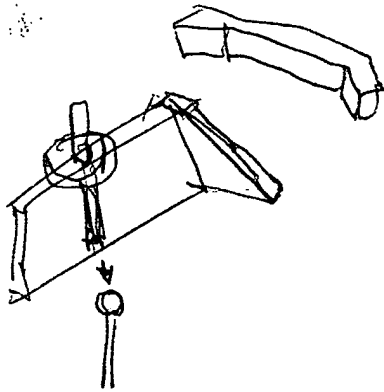
3 Phases:

- Rotation about x (3 positions!)
  data acquisition (accuracy -a $/02$
  (accuracy nb /sec
  Rotation
  coordinna[...]



- Rotation about y (3 positions!,

Rot point
(x, z)



- Rotation about z (3 positions

Rotation point
(x, y)



---
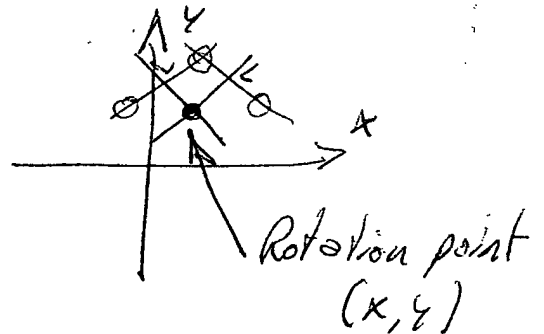
The 6 values should be redun[...]

⟹ Rotation point

With the emitter coordinate ⟹
Tip position from the descripti[...]

12/4/98

# ROBOT - HUMAN BEING INTERACTION

For safer reason, people don't like to work with robot because some hazardous movement can be created by the robot.

The idea for safer robot ~~XXXXXX~~ or manipulator is to use the energy of the human being but with the control of a computer. The computer will control brakes (on all or some joints) which can't generate hazardous movement !! in real time (300 Hz or more)

The control from the computer can be made through the position parameter, ~~XX~~ force measurement ~~XX~~, speed measurement.

~~XXX~~ Multiple applications can be done for medical guidance, for industrial manipulation to avoid the gravity effect, medical prothesis, medical rehabilitation, With sufficient degree of freedom this manipulator could be a universal computerized cam follower, etc

All these ideas have been shared with prof Oussama Khatib (computer science) during some brain storming meeting

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brakes (on all or some joints) ~~which can't~~ generate hazardous movemen
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The control from the computer can be made throu
the position parameter, ~~xxx~~ force measurement
speed measurement.

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rehabilitation, With sufficient degree of freedo
this manipulator could be a universal cam
cam follower, etc

All these ideas have been shared
with prof Oussama Khatib (compu
science) during some brain storming
meeting

Signed _____ Date

mputer can be meal through
~~xx~~ force measurement ~~xx~~,


ns can be done for medical
trial manipulation to avoid
medical pro~~sthe~~this, medical
different degree of freedom
uld be a universal computerized


s have been shared
me Khetto (computer
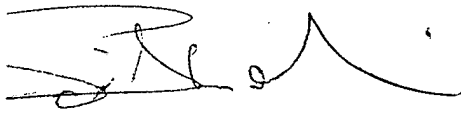some brain storming

Signed _~~Khetto~~_ Date 12/4/98

Marc Epitaux's last Day was: 12-4-98—

This Note Book Summarizes his efforts during his employment
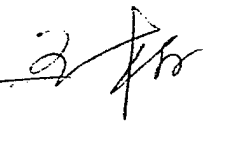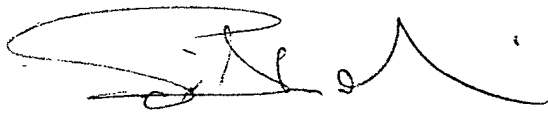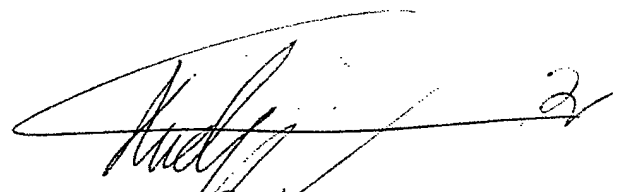
from April 1st 1998 till Now—

There are no empty pages upto page 51 (this page)

No pages are missing upto this page.

There are some (AD) DESIGNS attached at the

end of this Book.

Both Marc & Ramin Shahidi (PI) realizes that the

work Marc had Conducted at Image Guidance Laboratories

is the property of Image Guidance laboratories at

Stanford University—

Ramin Shahidi          Marc Epitaux          Bai Wang

Date   12-4-98.

Marc Epitaux's Last Day was - 12-4-98 -

This Note Book Summarizes his efforts during his empl.
from April 1st 1998 till Now -

There are no empty pages upto page 51 ( this page )
No pages are missing upto this page -

There are some (AI) Designs attached at the
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work Marc had conducted at Image Guidance labora
is the property of Image Guidance laboratories at
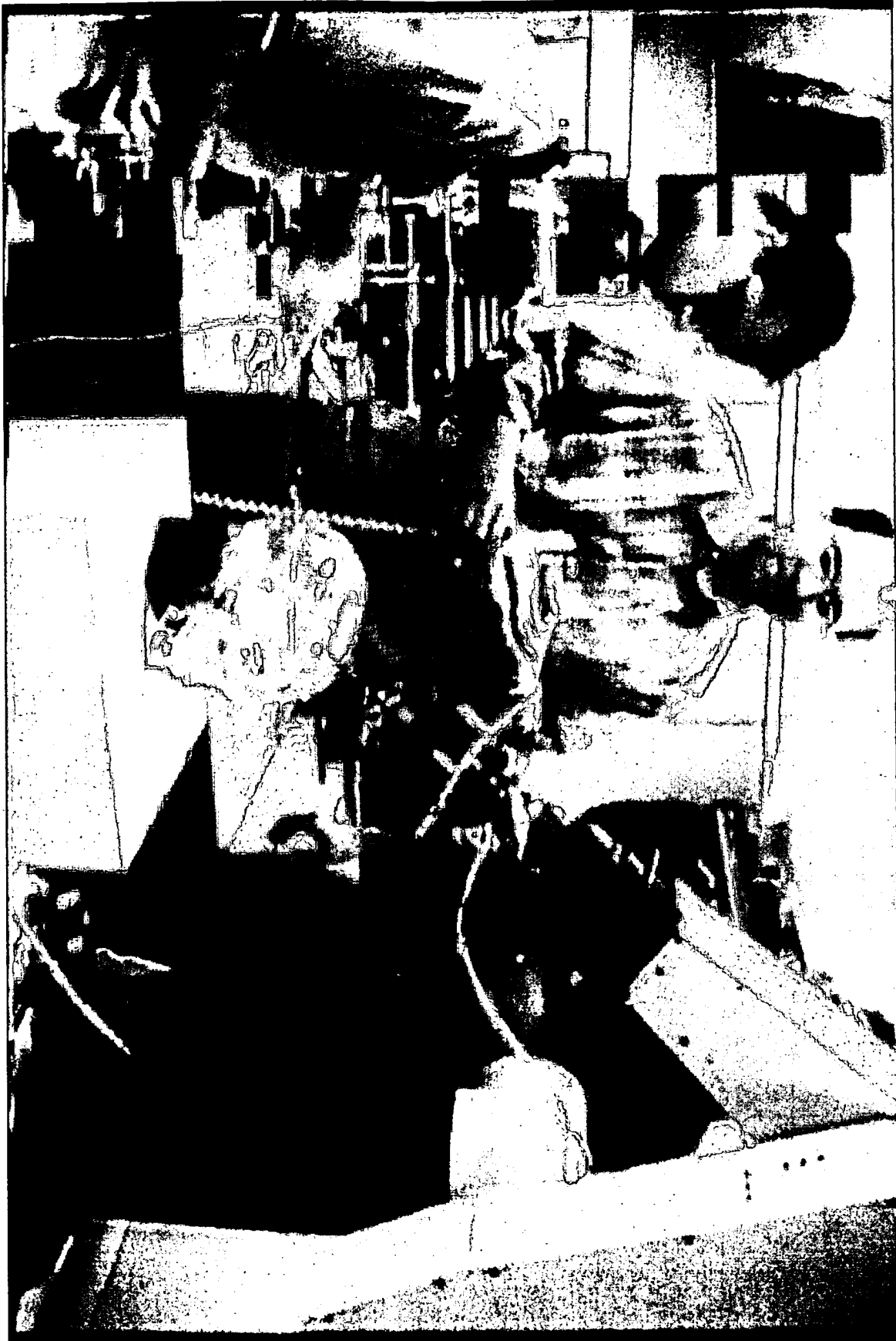Stanford University -

Ramin Shahidi                     Marc Epitaux          Bar

Date 12-4-98.

# EXHIBIT D

This Exhibit is a screen capture of the video of Exhibits B and C. The screen capture shows the robotic arm tracking an object inside a model of a human skull.
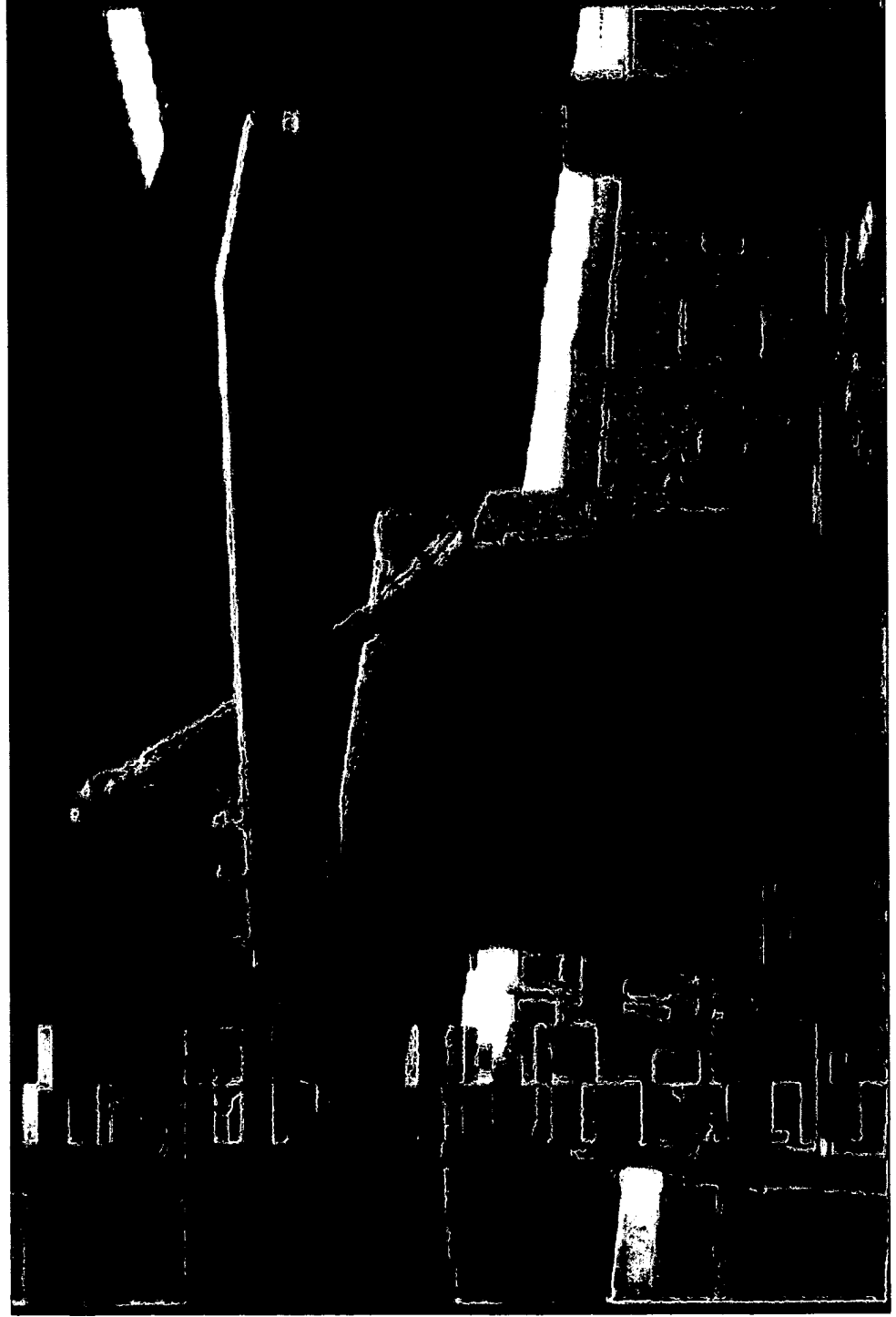
**EXHIBIT E**

This Exhibit is a screen capture of the video showing an optical tracking system. The optical tracking system is labeled "OTS". The label "OTS" was added subsequent to the creation of the image for identification purposes and was not in the video.

OTC
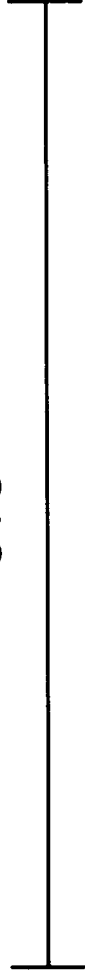
OTC

**EXHIBIT F**

Corporate information of CBYON, INC. printed from the California Secretary of State

web site. Indicating date of filing was January 6, 1999.

The information displayed here is current as of "DEC 26, 2008" and is updated weekly. It is not a complete or certified record of the Corporation.

| Corporation |
| --- |
| CBYON, INC. |
| **Number:** C2129748 **Date Filed:** 1/6/1999 **Status:** suspended |
| **Jurisdiction:** California |
| **Address** |
| 1675 N SHORELINE BOULEVARD |
| MOUNTAIN VIEW, CA 94043 |
| **Agent for Service of Process** |
| C T CORPORATION SYSTEM |
| 818 WEST SEVENTH ST |
| LOS ANGELES, CA 90017 |

Printer Friendly

**New Search**

- For information about certification of corporate records or for additional corporate information, please refer to **Corporate Records**.
- Blank fields indicate the information is not contained in the computer file.
- If the status of the corporation is "Surrender", the agent for service of process is automatically revoked. Please refer to California Corporations Code **Section 2114** for information relating to service upon corporations that have surrendered.

# UNITED STATES PATENT AND TRADEMARK OFFICE

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| APPL NO. | FILING OR 371 (c) DATE | ART UNIT | FIL FEE REC'D | ATTY.DOCKET NO | DRAWINGS | TOT CLMS | IND CLMS |
|---|---|---|---|---|---|---|---|
| 10/610,960 | 06/30/2003 | 3737 | 501 | 52755-8003.US02 | 7 | 9 | 6 |

22918
PERKINS COIE LLP
P.O. BOX 2168
MENLO PARK, CA 94026

DOCKETED

OCT 2 0 2003

PERKINS COIE LLP
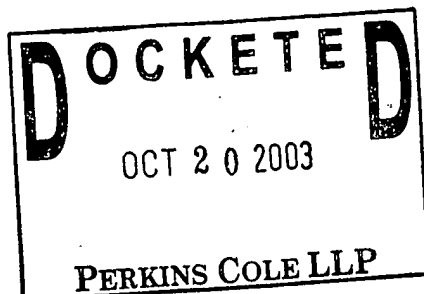
CONFIRMATION NO. 4157
FILING RECEIPT

*OC000000011004785*

Date Mailed: 10/08/2003

Receipt is acknowledged of this regular Patent Application. It will be considered in its order and you will be notified as to the results of the examination. Be sure to provide the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION when inquiring about this application. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. If an error is noted on this Filing Receipt, please write to the Office of Initial Patent Examination's Filing Receipt Corrections, facsimile number 703-746-9195. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections (if appropriate).

**Applicant(s)**

Ramin Shahidi, San Francisco, CA;

**Assignment For Published Patent Application**

The Board of Trustees of the Leland Stanford Junior University;

**Domestic Priority data as claimed by applicant**

This application is a CON of 09/792,485 02/23/2001 ABN
which claims benefit of 60/185,036 02/25/2000

**Foreign Applications**

**If Required, Foreign Filing License Granted:** 10/06/2003
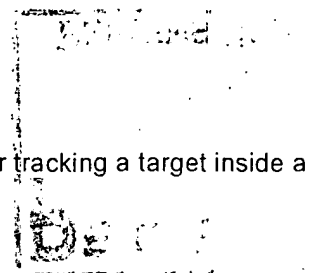
**Projected Publication Date:** 01/15/2004

**Non-Publication Request:** No

**Early Publication Request:** No

**\*\* SMALL ENTITY \*\***

**Title**

Methods and apparatuses for maintaining a trajectory in sterotaxi for tracking a target inside a

body

**Preliminary Class**
600

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